The International Surface Pressure Databank version 2

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Submitted to: Geoscience Data Journal

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Abstract

The International Surface Pressure Databank (ISPD) is the world's largest collection of global surface and sea level pressure observations. It was developed by extracting observations from established international archives, through international cooperation with data recovery facilitated by the Atmospheric Circulation Reconstructions over the Earth (ACRE) initiative, and directly by contributing universities, organizations, and countries. The dataset period is currently 1768–2012 and consists of three data components: observations from land stations, marine observing systems, and tropical cyclone best track pressure reports. Version 2 of the ISPD (ISPDv2) was created to be observational input for the Twentieth Century Reanalysis Project (20CR) and contains the quality control and assimilation feedback metadata from the 20CR. Since then, it has been used for various general climate and weather studies, and an updated version 3 (ISPDv3) has been used in the ERA-20C reanalysis in connection with the European Reanalysis of Global Climate Observations project (ERA-CLIM). The focus of this paper is on the ISPDv2 and the inclusion of the 20CR feedback metadata. The Research Data Archive at the National Center for Atmospheric Research provides data collection and access for the ISPDv2, and will provide access to future versions.

Dataset

Title: *International Surface Pressure Databank (ISPDv2)*

Identifier: doi: 10.5065/D6SQ8XDW

Authors: Compo, G. P., Whitaker, J. S., Sardeshmukh, P. D., Matsui, N., Allan, R. J., Yin, X., Gleason, B. E., Vose, R. S., Rutledge, G., Bessemoulin, P., Brönnimann, S., Brunet, M., Crouthamel, R. I., Grant, A. N., Groisman, P. Y., Jones, P. D., Kruk, M. C., Kruger, A. C., Marshall, G. J., Maugeri, M., Mok, H. Y., Nordli, O., Ross, T. F., Trigo, R. M., Wang, X. L., Woodruff, S. D., and Worley, S. J. (2010)

Publisher: Research Data Archive at the National Center for Atmospheric Research, Computational and Information Systems Laboratory, Boulder, Colorado, USA.

URL: http://dx.doi.org/10.5065/D6SQ8XDW

Introduction

The International Surface Pressure Databank (ISPD) is the world's largest collection of global surface and sea level pressure observations. Since its inception in 2002, its development has been facilitated by cooperative efforts between the Global Climate Observing System (GCOS)/World Climate Research Program (WCRP) Working Group on Observational Data Sets for Reanalysis [2007 to 2011], and the ongoing efforts of the GCOS Working Group on Surface Pressure and the international Atmospheric Circulation Reconstructions over the Earth initiative (ACRE, Allan et al. 2011). The full observational record is extracted and assembled from established international archives and newly available collections from more than 60 different contributing organizations, shown in Tables 1 and 2.

The ISPD version 2 (ISPDv2) covers the period 1768–2012. It merges data from three input components: observations from land stations, marine observing systems, and tropical cyclone best track pressure reports. The land station component was extracted from many national and international collections of sea level pressure and surface pressure. The largest contributor to this component was the Integrated Surface Database (Smith et al. 2011), which consists of global hourly and synoptic surface observations collected from many sources. The land stations were merged following a two-step algorithm to first remove duplicates within a collection and then remove duplicates between collections (Yin et al. 2008).

The marine component consists of sea level pressure observations extracted from the International Comprehensive Ocean–Atmosphere Data Set (ICOADS, Woodruff et al. 1998, Parker et al. 2004, Woodruff et al. 2005, Worley et al. 2005, Woodruff et al. 2011), a global ocean marine meteorological and surface ocean dataset that is considered the most complete of its kind. It is comprised of measurements and observations extracted from many international data sources, including ship reports, moored and drifting buoys, coastal stations, and other marine platforms. ICOADS release 2.4 was used in the ISPDv2 for the period 1952–2008 and ICOADS release 2.5 (Woodruff et al., 2011) was used for the period 1785–1951 and 2009–2012.

The tropical cyclone component was taken from the International Best Track Archive for Climate Stewardship (IBTrACS; Knapp et al. 2010). The IBTrACS dataset consists of global tropical cyclone best-track position and intensity observations, and reports collected from each of the World Meteorological Organization (WMO) Regional Specialized Meteorological Centers, Tropical Cyclone Warning Centers, and other national agencies. The IBTrACS Beta version was used for the years 1952–2006, version v01r01 for 1871–1883 and 1886–1951, version v02r01 for 1884–1885 and 2007–2008, version v03r02 for 2009–2010, and version v03r05 for 2011-2012.

The inclusion of various versions of both ICOADS and IBTrACS in ISPDv2 was the result of using the most up-to-date data that were available during the assimilation into the Twentieth Century Reanalysis (20CR; Compo et al. 2011). This rationale is elaborated upon in Section 2.1.

1. Dataset content and coverage

The ISPDv2 dataset is stored in the Hierarchical Data Format version 5 (HDF5: http://www.hdfgroup.org), which allows for efficient archiving of large, complex data structures and a diverse set of metadata. Each HDF5 file contains thirteen tables and fifteen directory subgroups that define how to decode the individual records, and each observation record includes metadata defining the data collection source and observation type (e.g., station observation, marine observation, surface pressure observation from a radiosonde sounding).

Because the ISPDv2 was assimilated as observational input into the 20CR, each record also includes the 20CR quality control and assimilation feedback metadata. These quality control and feedback metadata include the results of the five-step quality control procedure described in Appendix B of Compo et al. (2011) and all the relevant statistical quantities returned by the 20CR ensemble data assimilation system. The format of the HDF5 metadata, therefore, is designed to allow traceability of observations from their original source to the ISPDv2, and to permit direct feedback from the 20CR data assimilation back to the original source archives.

Each observation at any single observation time is assigned a unique number that when combined with the time stamp (year, month, date, hour, and minute) forms a unique identifier within the complete dataset. Thus, every observation has an unambiguous reference within the full ISPDv2 dataset, which allows for precise identification and traceability. This data management feature is critical for accurately adding additional metadata from other future reanalyses, and evolving the ISPDv2 to new versions while maintaining the usage provenance of each record.

The 20CR required hourly files from the ISPDv2 data for the data assimilation system, thus each data file in the ISPDv2 collection contains one hour of global observations. Based on this file organization and data coverage, a maximum of 24 data files per day and 8,760 data files per (non-leap) year exist in the ISPDv2 collection. The total dataset volume is 491.32 gigabytes. The HDF5 data are available for download as either individual hourly data files, or as yearly tar files, which are tarballs of one entire year of HDF5 data files.

The ISPDv2 is also available in NetCDF and ASCII column data formats, both of which are derived from the native HDF5 format. The data content within these two formats is not a complete reproduction of the tabular table content and metadata that is contained within the HDF5 data. It does contain, however, essential information, including the 20CR quality control feedback information, for most users to carry out their research projects. The ASCII data are available as monthly tar files for direct download from the National Center for Atmospheric Research (NCAR) Research Data Archive (RDA) website (http://dx.doi.org/10.5065/D6SQ8XDW), while the NetCDF data are produced on demand through the data subsetting service described in Section 3.1.

The data availability varies considerably over the period of record. Maps of annual land station distribution (Figure 1) highlight the steady growth in the number of reporting stations, and hence data coverage, since the year 1850 (station coverage maps for every year are available at http://www.esrl.noaa.gov/psd/data/ISPD/v2.0/). The sources of land station observations in the 19th and early 20th centuries are located primarily in Europe and North America. The data coverage increases dramatically across most of the rest of the globe from 1950 to the present.

Figure 2 shows time series of the total number of land observing stations in each indicated continental region by year from 1850–2010. The notable decline in stations during the mid-1960s—primarily in the Asia/Eastern Europe time series—is attributed to the reduction in the Integrated Surface Database records during this period, and is explained in Smith et al. (2011) as the result of the transition from keying of observational data to digital transmission and receipt of data.

The Asia time series also exhibits a considerable decline in station coverage starting in the mid-1980s. A listing of the number of stations originating from the Integrated Surface Database for the years 1963–1964 and selected years between 1980–2001 is shown in Table 3, which reveals these reductions are primarily associated with the observations originating from the Russian Federation and other former Soviet Union countries. These reductions can be explained by the deterioration of funding of the meteorological observation network in the final years of the Soviet Union existence and thereafter in the 1990s and 2000s. The observation network health during this post-Soviet period was a function of the economic situation in each of the 15 newly independent nations (and, to some extent, a function of foreign sponsorship). The China, North and Central America, and South-West Pacific regions also exhibit notable decreases between 1963–1964.

The average number of pressure observations per day contained in the 20CR feedback records from all ISPDv2 components (station, marine, and tropical cyclone) is illustrated by maps for the years 1900, 1950, and 2000 in Figure 3. The preponderance of observations in the Northern Hemisphere in earlier years is evident, as is the growth of marine observations over time (see Woodruff et al. 2011 for a complete description).

The total number of observations per year in the ISPDv2 increases steadily from approximately 100,000 records in 1870 to 53 million in 2010 (Figure 4). A local increase and subsequent decrease in this trend during the 1878–1894 period is attributed to the addition of 1.8 million records from the US Marine Meteorological Journals and digitized for ICOADS Release 2.5 (Woodruff et al. 2011). A decrease during the World War I years is evident, while an increase during the World War II years is attributed to the inclusion of 1.6 million ICOADS records digitized from the UK Royal Navy Ships' logbooks (Brohan et al. 2009; Woodruff et al. 2011). A decrease during the mid–1960s is associated with the aforementioned decline in station records in the Integrated Surface Database (Smith et al. 2011). A decrease in 2007 is most likely due to a delay in processing, and therefore incomplete records, in the Integrated Surface Database. Other small-scale variations in the curve likely can be correlated to increased scientific interest (local peaks) and research budget reductions (local troughs; Fleming 2000).

The dataset contains reports from more than 10,000 land stations, which, in addition to the marine observing systems reports, comprise over 1.5 billion observations in total. Between 1860 and 1917, the total number of marine and surface station observations is comparable, but in later years the total count is dominated by land surface station reports (not shown). This prevalence of land station observations is primarily due to the input data compiled for the National Centers for Environmental Prediction (NCEP)/NCAR Reanalysis project (1948–2003; Kalnay et al. 1996, Kistler et al. 2001).

2. Data usage and application

2.1 Reanalysis

The primary motivation for the creation and development of the ISPD was to facilitate progress on research and understanding of long-term trends and variations in global surface pressure. In particular, a long–term historical dataset, such as the ISPD, becomes essential to providing an observational underpinning to retrospective climate analysis datasets, commonly known as reanalyses. Reanalysis products are used extensively in climate research, applications and services, including for monitoring and comparing current climate conditions with those of the past, identifying the causes of climate variations and change, and preparing climate predictions. Information derived from reanalyses is also being used increasingly in commercial and business applications in sectors such as energy, agriculture, water resources, and insurance.

Prior to completion of the ISPD, most reanalysis products (including those from the NCEP/NCAR Reanalysis Project [Kalnay et al. 1996, Kistler et al. 2001] and the European Centre for Medium-Range Weather Forecasts [ECMWF; Uppala et al. 2005]) could only extend back to about 1950 since they relied on assimilating a set of observations that included upper-level atmospheric information. The primary input data source for the NCEP/NCAR Reanalysis, for example, are the global rawinsonde observations, which contain a period of record substantial enough to produce that reanalysis back to 1948. The limited time range of these reanalyses restricts their usefulness for many climate research applications. The ISPD adds value by providing a much longer period of record and thus enables the development of reanalyses with longer time spans.

The first reanalysis to make use of the ISPD is the 20CR Project (Compo et al. 2011), which assimilates only the ISPDv2 surface and sea level pressure observations and prescribes observed monthly sea–surface temperature and sea–ice distributions from HadISST1.1 (Rayner et al. 2003) as boundary conditions. This global reanalysis dataset spans the late-nineteenth century, the entire twentieth century, and the early twenty–first century (1871–2012). It estimates the state of the atmosphere—the "analysis"—by combining the hourly and synoptic ISPDv2 observations in a six-hour time window with a dynamically generated nine–hour first guess forecast initialized from the previous analysis. Cycling this procedure with overlapping six–hourly analyses and nine–hour forecasts has the effect of spreading the observational information from the ISPD three-dimensionally in space and in time.

As the 20CR was produced, the early period ISPDv2 "beta" version was revised to include newly digitized additions and improve the overall coverage of stations. As ICOADS Release 2.5 was then available, it was also included to increase the number of marine observations in the early period. Similarly for IBTrACS, newly digitized records from the most recent versions of IBTrACS were added to ISPDv2 as it evolved and improved over time. The final ISPDv2, therefore, contains multiple source versions of ICOADS and IBTrACS. The newer versions of ICOADS and IBTrACS did not change appreciably except to expand their data inputs and coverage, therefore we do not anticipate that the use of multiple versions introduces inconsistencies in the pressure dataset.

2.2 Twentieth Century Reanalysis quality control and data assimilation feedback

During the data assimilation processing of the 20CR, the ISPDv2 input data were interrogated by a five-step quality control procedure that included, among other steps, checking the observations for meteorological plausibility, comparing them with neighboring data values, and performing a bias correction on the land component (see Compo et al. 2011 for more information on this procedure). The 20CR then applied an Ensemble Kalman Filter data assimilation method which used background first-guess fields supplied by an ensemble of 56 forecasts from an experimental version of the NCEP Global Forecast System (GFS) numerical weather prediction model (Kanamitsu et al. 1991, Moorthi et al. 2001, Saha et al. 2006). These quality control and data assimilation results, which include the first-guess fields, analysis departures, bias estimates, and observation errors, were then written back into the ISPDv2 so that each observational record contains this feedback information. Future users of the ISPDv2, and those who contributed the original observational data, therefore can utilize this information to make an informed decision on the quality and usefulness of each observational record during the 20CR time period.

One project that utilized the 20CR feedback metadata is the ERA-20C reanalysis (Poli et al. 2013), which is the first reanalysis produced under the European Reanalysis of Global Climate Observations database project (ERA-CLIM: www.era-clim.eu). The ERA-20C is a global reanalysis that spans the twentieth century (1900–2010) assimilating only surface and sea level pressure observations from ISPD and ICOADS and marine surface winds from ICOADS. Feedback information from the 20CR was used in the bias-correction scheme for ISPD data that were assimilated in the ERA-20C reanalysis; this was based on a break-point analysis using the 20CR first-guess departures (Hersbach et al. 2015). In locations where breakpoints were suspected (for example, instances of instrument errors or a change in station location), the ERA-20C bias correction scheme assigned less confidence to the 20CR first-guess value, and thus was allowed to be more adaptive compared to cases where no irregularities in long-term departures were identified.

In another study, Wang et al. (2014) used the 20CR feedback metadata to show that the strong extratropical cyclone events in the 20CR agree well with the geostrophic wind extremes derived from in-situ pressure observations. This study illustrates how the 20CR quality control procedure performed well in identifying errors in the observational record. For example, the 20CR quality control system identified and rejected 143 out of 146 erroneous observation values from the Aberdeen, Scotland records for the period 1871–1921. This quality control feedback information, therefore, is valuable in identifying observation errors which might otherwise be overlooked and, coupled with continued data rescue efforts such as those facilitated by ACRE (Allan et al. 2011), serves to strengthen and reduce uncertainty in the observational record.

3. Data access and user services

3.1 Research Data Archive data location and accessibility

The primary repository for ISPDv2 is in the RDA (http://rda.ucar.edu) at NCAR in Boulder, Colorado. The RDA is a free and open data collection where data discovery can be achieved through faceted searches based on Global Change Master Directory (GCMD: http://gcmd.nasa.gov) metadata keywords, free text queries, and lists highlighting the most used datasets. Data access is free, but requires each user to register through a simple online process that validates the submitted email address.

The ISPDv2 data access is organized by year and month on the RDA website (http://dx.doi.org/10.5065/D6SQ8XDW), and users may browse through the pages to locate specific data of interest. Data files are organized in default groups by observation year and month. They can be downloaded directly from the RDA web interface using server-supplied “wget” scripts. Users may select a collection of files to download from default lists by using the “Web File Listing” option under the “Data Access” tab.

A more refined option is provided through the data subset request form, which may be accessed via the "Get a subset" link under the "Data Access" tab. This produces a customized data subset of the HDF5 data based on user-provided constraints. Users can specify the temporal limits, spatial domain, observation type(s), and ASCII or NetCDF data output formats through the data subset request form (Figure 5). The output file compression can also be requested on this form (not shown). Observations from individual observing stations may also be requested, which is a useful feature for users who wish to procure time series for specific locations or regions. Once submitted, data subset requests are produced by a delayed mode data processing procedure. Users are notified and directed to a web download location when their data request output files are accessible.

3.2 Dataset citation

The RDA also provides a data citation service. The dataset homepage provides citation syntax in the standard forms recommended by the Federation of Earth System Information Partners (ESIP), American Meteorological Society (AMS), American Geophysical Union (AGU), DataCite, and the Geoscience Data Journal. This dataset citation is also available in Research Information System (RIS) format so that users may import the citation for this dataset directly into their citation reference management software (e.g. EndNote, Zotero, etc.). One key element in the dataset citation is the data access date ('Accessed dd mmm yyyy'). Leveraging the fact that RDA data users are registered, a customized data citation can be prepared for the user by using the "Get a customized data citation" link on the dataset home page. The dates that users access the data are recorded and can be retrieved on demand at later times.

3.3 File content metadata

File content metadata are collected as part of the data processing and preparation of the ISPDv2 for the RDA. The metadata supports additional information services for interested users. The overall ISPDv2 metadata summary is provided from the dataset home page under the "More Details" link. Here tabulations of the observing station location, observation type, platform identification, and maps of the global distribution for the full ISPDv2 can be viewed (Figure 6).

In addition, users may view the content metadata for the yearly tar file archives by clicking on a looking glass icon adjacent to the tar file listing, accessible under the "Data Access" tab. This service enables users to query the ISPDv2 via an interactive map of land station locations, and more efficiently determine the observational data available at any particular time and region of interest (Figure 7).

3.4 Supporting software and documentation

Source code developed at the University of Colorado CIRES and NOAA Earth System Research Laboratory and written in C language to read and decode the HDF5 data into ASCII column output is provided on the RDA website under the "Software" tab on the dataset home page. Documentation describing the HDF5 tables and ASCII output is also available for download under the "Documentation" tab on the dataset home page.

3.5 ECMWF data location and accessibility

A subset of the ISPDv2 is also archived at ECMWF (http://apps.ecmwf.int/datasets). Here, users may extract temporal subsets from the ISPDv2 archive stored at ECMWF and refine their selection by observation platform. The output from these requests is written in ASCII column format and contains the date, location, observed value, report type, unique identifier which allows traceability to other ISPD versions, and several feedback parameters from the 20CR, including the 20CR bias estimate, the 20CR ensemble mean first guess pressure minus the "modified" observed pressure, and the ensemble mean analysis pressure minus the "modified" observed pressure. The "modified" pressure is the pressure value after the 20CR system adjusted it to be consistent with the orography in the assimilating model. This is similar to a reduction to sea level but instead is an adjustment to the 20CR orography, which could be higher or lower than the station elevation. In addition to the ASCII output, users may produce observation count maps for their data selection on the ECMWF web interface.

4. Future plans

Since the release of ISPDv2, over 22 additional organizations have contributed to the station and marine components of the ISPD (Table 1) and the period of record now extends back to 1755. These new contributions have been incorporated into a newer version 3 of the ISPD (ISPDv3), which will be made available in the near future through the NCAR RDA. The observation feedback archive (OFA) version of this dataset as used in the ERA-20C reanalysis is available from ECMWF (Hersbach et al. 2015).

The gain in observations for ISPDv3 is illustrated by the time series shown in Figure 8. Most of the increase occurs in the Northern Hemisphere, and there are visible increases in the late 19th century and during the World War I years. The 2007 decrease in merged records from the Integrated Surface Database into ISPDv2 (cf. Figure 4) is recovered in ISPDv3. These and increases in other years come from diverse station and marine collections contributed to the ISPD under the auspices of GCOS, WCRP, and the ACRE initiative. This includes the initial efforts of the OldWeather.org citizen science project that focused on UK Royal Navy observations during 1914–1923, the citizen-led Todd Project team (http://www.charlestodd.net) that focused on recovering observations assembled by Sir Charles Todd, Meteorologist of the Colony of South Australia during 1879–1909, and the efforts of many other university, national, and international organizations (Table 1). Another notable contribution are the North African locations, which arose from the joint effort between the European Union–funded EUropean Reanalysis and Observations for Monitoring (EURO4M: http://www.euro4m.eu) project in connection with the WMO/MEditerranean climate DAta REscue (MEDARE) initiative (http://www.omm.urv.cat/MEDARE; Brunet et al. 2014). The merging of these contributions results in increases that are particularly dramatic when viewed as a map, as shown for the example year of 1918 (Figure 9). The increases over eastern South America, eastern Africa, China, New Zealand, and selected central Pacific islands are especially evident.

ISPDv3 (specifically, version 3.2.6) was implemented into the European Reanalysis of Global Climate Observations database (ERA-CLIM: www.era-clim.eu), with a goal of using these and additional observations in an ECMWF data assimilation system to generate new global climate reanalyses of the twentieth century. The ERA-20C global reanalysis, the first reanalysis under this project, spans the twentieth century (1900–2010) assimilating only surface and sea level pressure observations from ISPDv3 and marine wind observations from ICOADS 2.5 using a 4D-Var assimilation system (Poli et al. 2013).

In addition, ISPD version 3.2.9 is being assimilated into the next generation of the 20CR (version 2c). 20CRv2c uses the same NCEP atmosphere/land coupled model at the same spectral resolution of total wavenumber 62 (about 200 km by 200 km) as 20CRv2 but has different prescribed boundary conditions. Daily sea surface temperatures come from a new Simple Ocean Data Assimilation with sparse input version 2 (SODAsi.2, Giese et al. 2015, in preparation). Prescribed monthly averaged sea ice concentrations from the new COBE-SST2 (Hirahara et al. 2014) correct the known misspecification in 20CRv2 (Compo et al. 2011, Brönnimann et al. 2012). This activity is currently underway and will be reported on in due course.

The ISPD also will be used in the planned centennial coupled reanalysis being developed under the Japanese research project Program for Risk Information on Climate Change (SOUSEI: http://www.jamstec.go.jp/sousei/eng/research/theme_a.html), by the Meteorological Research Institute of the Japan Meteorological Agency and collaborators (M. Ishii, personal communication, 2014).

Comments and questions on the ISPD can be directed to the RDA data specialist or left at the reanalyses.org webpage for this dataset (http://reanalyses.org/observations/international-surface-pressure-databank).

Acknowledgements

Construction of the ISPD is supported by the U.S. Department of Energy Office of Science (Biological and Environmental Research program) and the NOAA Climate Program Office. The Twentieth Century Reanalysis Project and the International Surface Pressure Databank used resources of the National Energy Research Scientific Computing Center and of the Oak Ridge Leadership Computing Facility at Oak Ridge National Laboratory, which are supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231 and Contract No. DE-AC05-00OR22725, respectively. Manola Brunet and Philip D. Jones are grateful to the European Union–funded projects EUropean Reanalysis and Observations for Monitoring (EURO4M, FP7-SPACE-2009-1 Project No. 242093) and Uncertainties in Ensembles of Regional Reanalyses (UERRA, FP7-SPACE-2013-1 Project No. 607193). Pavel Groisman was partially supported by Grant 14.B25.31.0026 of the Russian Ministry of Education and Science. Renate Auchmann was supported by the Swiss National Science Foundation (SNF; Project TWIST, 200021_146599/1).

The authors would like to thank the following individuals and organizations for their contributions:

Rajmund Przybylak of the Nicolaus Copernicus University, Department of Meteorology and Climatology, Poland.

Frank Le Blancq and many others, Jersey Met Service, for Channel Island data.

The IT group at CIRES and NOAA/ESRL Physical Sciences Division.

Prashant Sardeshmukh of University of Colorado/CIRES for valuable guidance and input.

Paul Della-Marta and MeteoSwiss colleagues who originally provided data to EMULATE.

Ingeborg Auer of Zentralanstalt für Meteorologie und Geodynamik (ZAMG) who originally provided Austrian data to EMULATE.

Clive Wilkinson of NCDC and Climatic Research Unit, University of East Anglia, Norwich, UK, and Eric Freeman of NCDC for World War II UK Royal Navy Data.

David Tse of Hong Kong Observatory for Hong Kong data.

Volker Wagner for a subset of the Deutscher Wetterdienst HISTOR marine data.

Società Meteorologica Italiana (SMI) for the Torino record.

Mac Benoy and the Australian Meteorological Association, Todd Project team

Dick Dee, ECMWF, and the ERA-CLIM project

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Sam Dean of National Institute of Water and Atmospheric Research (NIWA), Auckland, New Zealand for productive conversations.

The following persons affiliated with the University of Giessen, Germany digitized subdaily pressure data originating from Europe, Asia, Africa, northern South America, and the Caribbean:
Christine Kolbe, Lisa Flender, Marina Ostheimer, Johanna Englhardt, Athanasios Tsikerdekis, Lamprini Dergianli, Despina Xoplaki, Christos Samaras, Eleni Kaimasidou, Nancy Gouta, Elisabet Tsalkitzidou, Mary Athanasiou, Christakis Athanasiou, Panagiota Katsaouni, Alexander Theocharis, Stella Dafka, Kevin Pometti, Gail Kelly, Elda Fleitmann, Lisa Theile, Petra Strehlau, Ines Stange, and Jonas Viezens.

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Table 1. Contributing organizations to the International Surface Pressure Databank. Contributors to version 2 are indicated with an asterisk (*) (cf. Compo et al. 2011, Table II).

1.	*All-Russian Research Institute of Hydrometeorological Information World Data Center
2.	*Atmospheric Circulation Reconstructions over the Earth (ACRE)
3.	*Australian Bureau of Meteorology
4.	Australian Meteorological Association, Todd Project team
5.	*British Antarctic Survey
6.	Cook Islands Meteorological Service
7.	*Danish Meteorological Institute
8.	*Deutscher Wetterdienst (DWD)
9.	*Environment Canada, Climate Research Division
10.	*ETH Zurich, Switzerland
11.	*European and North Atlantic Daily to Multidecadal Climate Variability (EMULATE)
12.	EUropean Reanalysis and Observations for Monitoring (EURO4M)/The WMO MEditerranean DAta REscue Initiative (MEDARE)
13.	European Reanalysis of Global Climate Observations (ERA-CLIM)
14.	*GCOS Atmospheric Observation and Ocean Observation Panels for Climate Working Group on Surface Pressure
15.	*GCOS/WCRP Working Group on Observational Data Sets for Reanalysis
16.	*Hong Kong Observatory
17.	Icelandic Meteorological Office (IMO)
18.	*Instituto Geofisico da Universidade do Porto, Portugal
19.	*International Best Track Archive for Climate Stewardship (IBTrACS)
20.	*International Comprehensive Ocean–Atmosphere Data Set (ICOADS)
21.	*International Environmental Data Rescue Organization (IEDRO)
22.	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
23.	*Japan Meteorological Agency
24.	*Jersey Met Department
25.	*Koninklijk Nederlands Meteorologisch Instituut (KNMI; Royal Netherlands Meteorological Institute)
26.	Lamont-Doherty Earth Observatory of Columbia University
27.	McGill University, Canada
28.	*Met Office Hadley Centre, UK
29.	*Météo-France
30.	Météo-France – Division of Climate
31.	*Meteorological and Hydrological Service, Croatia
32.	*National Center for Atmospheric Research (NCAR), USA
33.	National Institute for Water and Atmospheric Research (NIWA), New Zealand
34.	Nicolaus Copernicus University–Department of Meteorology and Climatology, Poland
35.	Niue Meteorological Service
36.	*NOAA Climate Database Modernization Program (CDMP), USA
37.	*NOAA Earth System Research Laboratory (ESRL), Physical Sciences Division, USA
38.	*NOAA Midwest Regional Climate Center at UIUC, USA
39.	*NOAA National Centers for Environmental Prediction (NCEP), USA
40.	*NOAA National Climatic Data Center (NCDC), USA
41.	*NOAA Northeast Regional Climate Center at Cornell University, USA
42.	NOAA Pacific Marine Environmental Laboratory, USA
43.	*Norwegian Meteorological Institute
44.	*Ohio State University—Byrd Polar Research Center, USA
45.	Oldweather.org
46.	Portuguese Institute of Sea and Atmosphere (IPMA), Portugal
47.	*Proudman Oceanographic Laboratory, UK
48.	*Signatures of environmental change in the observations of the Geophysical Institutes (SIGN)
49.	*South African Weather Service
50.	South Eastern Australian Recent Climate History (SEARCH) project, The University of Melbourne
51.	Tanzania Meteorological Agency

52.	University of Abderdeen, Scotland, UK
53.	University of Bern, Switzerland
54.	*University of Colorado—Climate Diagnostics Center (CDC) of the Cooperative Institute for Research in Environmental Sciences (CIRES)
55.	*University of East Anglia—Climatic Research Unit, UK
56.	University of Giessen—Department of Geography, Germany
57.	*University of Lisbon—Instituto Dom Luiz, Portugal
58.	*University of Milan—Department of Physics, Italy
59.	*University of Porto-Instituto Geofisico, Portugal
60.	*University Rovira i Virgili—Centre for Climate Change (C3), Spain
61.	University of South Carolina, USA
62.	University of Toronto—Department of Physics, Canada
63.	University of Washington, USA
64.	World Meteorological Organization—MEditerranean climate DAta REscue (MEDARE)
65.	*Zentralanstalt für Meteorologie und Geodynamik (ZAMG; Austrian Weather Service)

Table 2. ISPDv2 dataset collection identifiers and names. The columns denote, respectively, the ISPDv2 collection ID, collection name, description, yearly period of record, total number of stations and observational records in the collection, reference number for the corresponding National Climatic Data Center (NCDC) dataset, reference number for the corresponding dataset archived in the Research Data Archive (RDA) at the National Center for Atmospheric Research (NCAR), and reference publication.

ISPD ID	Name	Description	Period	# Stations /Records	NCDC Ref	NCAR Ref	Reference Publication
0100	ICOADS Release 2.1	Global Marine Surface Observations	1784–2005	–/ ~185 million	DSI-1170	ds540.0, ds540.1	Parker et al. (2004), Woodruff et al. (1998), Woodruff et al. (2005), Worley et al. (2005)
0104	ICOADS Release 2.4	Global Marine Surface Observations	1784–2007	–/ ~238 million	DSI-1170	ds540.0, ds540.1	Parker et al. (2004), Woodruff et al. (1998), Woodruff et al. (2005), Worley et al. (2005)
0105	ICOADS Release 2.5	Global Marine Surface Observations	1784–2007	–/ ~261 million	DSI-1173	ds540.0, ds540.1	Woodruff et al. (2011)
0200	ICOADS Auxiliary Kobe	Global Marine Surface Observations	1889–1943	–/3,135		ds530.0	
0300	ICOADS Auxiliary Whaling	Global Marine Surface Observations	1950–1984	–/20		ds530.0	
0400	ICOADS Auxiliary Russian	Global Marine Surface Observations	1950–2000	–/1,789		ds530.0	
0500	ICOADS Auxiliary Russian	Global Marine Surface Observations	1889–2000	–/7,873		ds530.0	

0700	ICOADS Auxiliary Challenger	Global Marine Surface Observations	1872–1876	(n/a)		ds530.0	
1000	Federal Climate Complex Integrated Surface Database	Global Land Surface Observations	1901–2008	23,363/ ~1.2 billion	DSI-3505	ds463.3	Smith et al. (2011)
1002	CDMP SAO/1001 Forms	US Land Surface Observations	1928–1948	27/236,886	DSI-3851		Dupigny-Giroux et al. (2007)
1003	Russian Empire Stations	Russian Land Surface Observations	1849–2000	1,860/ 87,795,180	DSI-9290c		
1004	Air Weather Service TD13	Global Land Surface Observations	1901–1973	32/55,748		ds467.0	
1005	Hadley Centre	Individual Stations from Hadley Centre	1833–present	11/520,594			Allan et al. (2011)
1006	CDMP-International	Chile, Mexico, Uruguay	1800s–1980	14/326,175			Dupigny-Giroux et al. (2007)
1007	READER Antarctic & Southern Hemisphere	20 Stations via British Antarctic Survey	1947–2007	18/562,784			
1010	U.S. Air Force DATSAV	US Air Force Compilation	1976–1980		DSI-9685	ds463.0	
1011	Royal Netherlands Meteorological Institute (KNMI)	KNMI stations	1911–2006	3/ 1,045,250			
1012	CDMP Forts	US Army Signal Service and other 19th Century Voluntary Observations	1841–1893	49/629,491	DSI-3297		Dupigny-Giroux et al. (2007)

2000	NCEP-NCAR BUFR Archive	Global Observations	1948–2003	6,625/ 26,225,199		ds090.0	Kalnay et al. (1996), Kistler et al. (2001)
2001	NCEP Operational BUFR Archive	Global Observations	1928–1948, 2003–2005	1,053/ 2,940,516		ds090.0	
3002	WASA Stations Observations Sea Level Pressure	Northern Europe, Greenland	1871–1996	20/ 2,181,628			Schmith et al. (1997), Schmith et al. (1998)
3004	Environmental Canada Pressure Observations	Canadian Stations	1842–2004	746/ 25,277,856			
3005	West African Synoptic observations	West African Land Surface	1850–1980	123/ 3,022,702			
3006	The Australian Bureau of Meteorology Station Pressure Dataset	Australian Land stations	1900–1956	63/ 1,418,093			
3007	Northern Italian Pressure Observations		1878–1940	1/62,253			Maugeri et al. (2004), Maugeri et al. (2008)
3008	Brazil Surface Observations		1951–1980	8/78		ds486.0	
3009	Spanish Hourly Pressure Observations from EMULATE	Hourly Spanish Land Stations	1850–2003	5/190,899			Ansell et al. (2006)
3010	Germany	Deutscher Wetterdienst (DWD) Web Archive	1876–2000	9/405,167			
3011	Austria	Emulate Stations	1872–2002	9/467,124			Ansell et al. (2006)

3012	Switzerland	Emulate Stations	1900–1973	8/815,363			Ansell et al. (2006)
3013	South Africa	South African Weather Service Stations	1850–2003	187/ 2,636,479			
3014	Norway		1863–2007	16/225,687			
3015	Croatia Meteorological and Hydrological Service Land Stations	Land Stations	1858–2005	4/444,398			
3016	Portugal	Portuguese SIGN stations	1860–2006	2/151,989			Valente et al. (2008)
4000	Hong Kong Hourly Pressure Observations	Hong Kong Observatory	1885–1939	1/430,920			
4001	Jakarta/Batavia Pressure Observations	Dutch Royal Observatory	1866–1944	1/604,518		ds490.0	
4002	Liverpool	Proudman Ocean. Lab stations	1768–1793	1/9,094			
4003	Jersey Channel Island Pressure Observations	Channel Island Stations	1864–1913	7/159,781			
4004	CMDP-USNO	US Naval Observatory at Washington	1841–1913	1/83,261			Dupigny-Giroux et al. (2007)
5000	Antarctic Expedition keyed by Hadley Centre		1899–1941	11/119,991			Allan et al. (2011)
5002	Byrd Antarctic Expeditions Observations	Monthly Weather Review Supplemental No. 41	1929–1930				

8000	Atlantic/ North Eastern Pacific Hurricane Reanalysis	US Hurricane Re–Analysis Dataset	1848–present				
8001	International Best Track Archive for Climate Stewardship (IBTrACS)	National Climatic Data Center	1848–present		DSI-9637		Knapp et al. (2010)
010000 – 019999	NCAR Upper Air Stations	National Center for Atmospheric Research	1943–1998	1,081/ 1,275,272		ds370.1	

Table 3. Total number of stations originating from the Integrated Surface Database and included in ISPDv2 for selected years between 1963–2001. The columns represent the station count for the years listed and organized by WMO regional block number (0 and 1 = Europe; 2 and 3 = Russian Federation and other former Soviet Union countries; 4 = Asia; 5 = China; 6 = Africa; 7 = North America, Central America, and the Caribbean; 8 = South America and Antarctica; and 9 = South-West Pacific).

WMO region	1963	1964	1980	1990	1993	1995	1998	2001
0	47	28	877	1007	925	927	869	1058
1	184	166	717	813	740	748	777	935
2	914	223	800	695	683	577	410	482
3	795	124	1031	878	835	751	607	584
4	466	353	916	932	864	876	867	1049
5	518	347	727	598	592	587	558	638
6	211	222	689	768	758	776	825	887
7	484	280	1524	1594	1671	1697	1560	1770
8	132	132	550	695	661	684	630	671
9	689	626	578	865	874	898	860	841

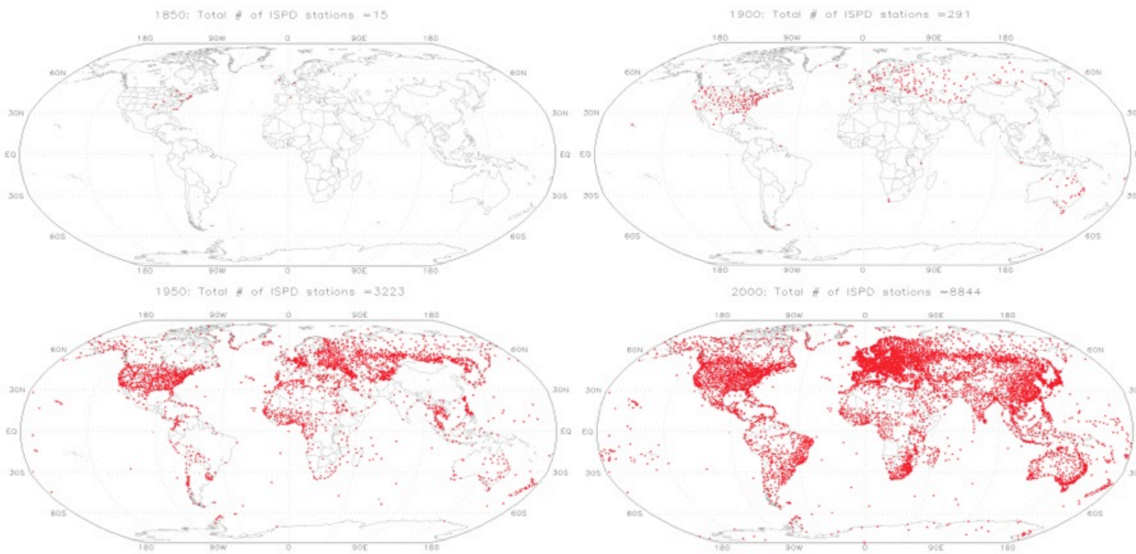


Figure 1. Annual distribution of ISPDv2 land station locations for the years 1850, 1900, 1950, and 2000. Station coverage maps for every year in the ISPDv2 are available at http://www.esrl.noaa.gov/psd/data/ISPD/v2.0/.

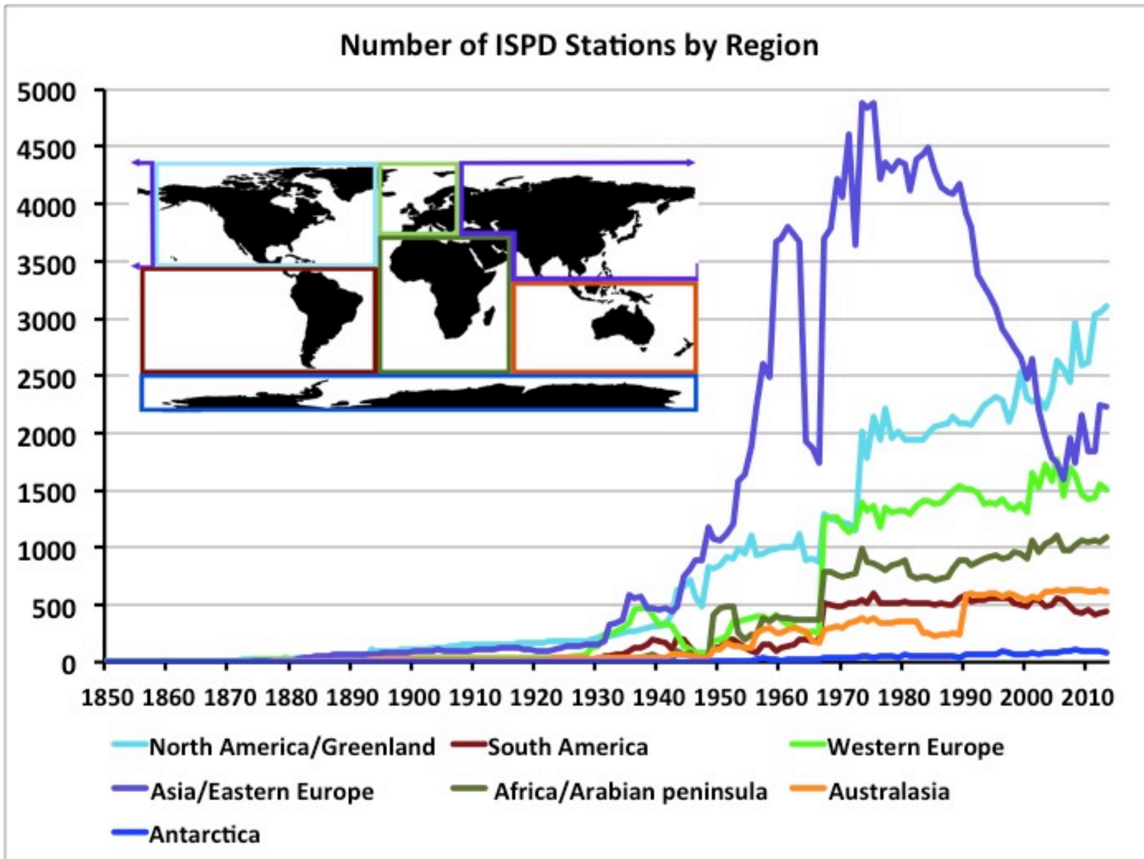


Figure 2. Time series of the total number of ISPDv2 land observing stations in each indicated continental region by year from 1850–2010. The inset panel indicates the boundaries used for the continental regions.

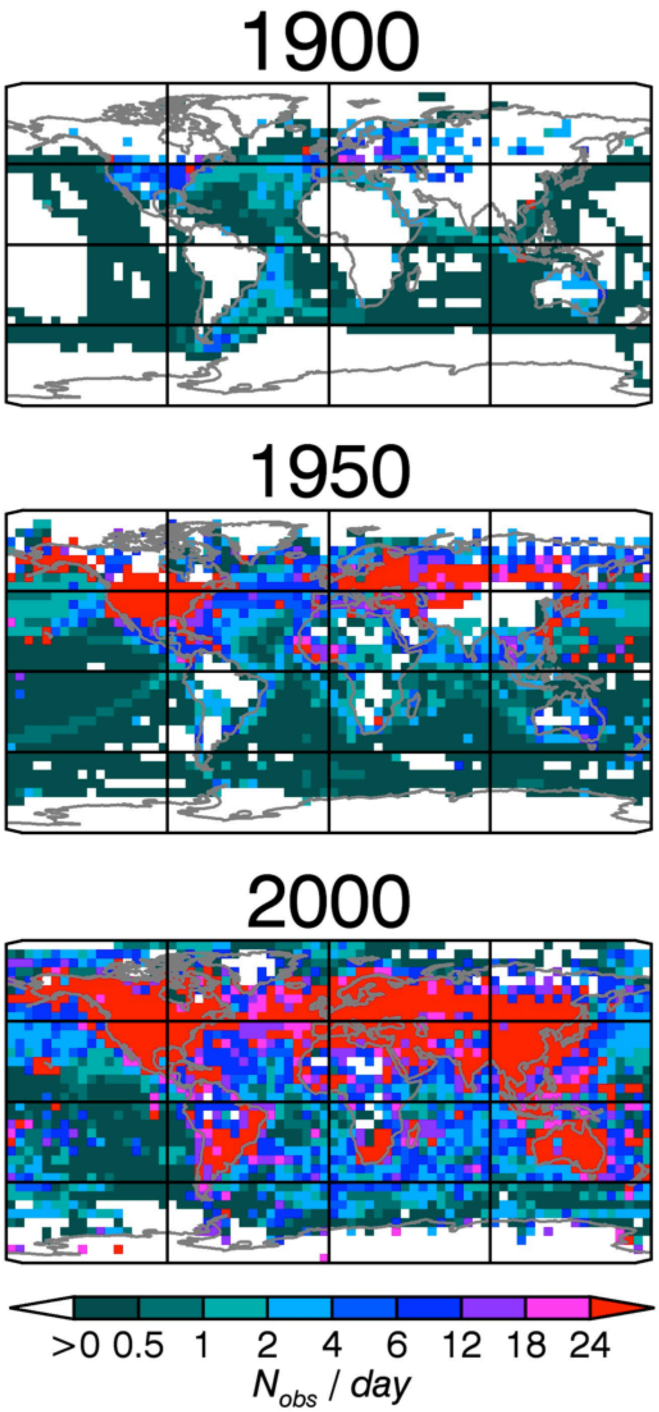


Figure 3. Maps showing the average number of pressure observations per day contained in the 20CRv2 feedback records from all ISPDv2 components: station, marine, and tropical cyclone for the years 1900 (top), 1950 (middle), and 2000 (bottom). Counts of observations are made in five-degree grid boxes.

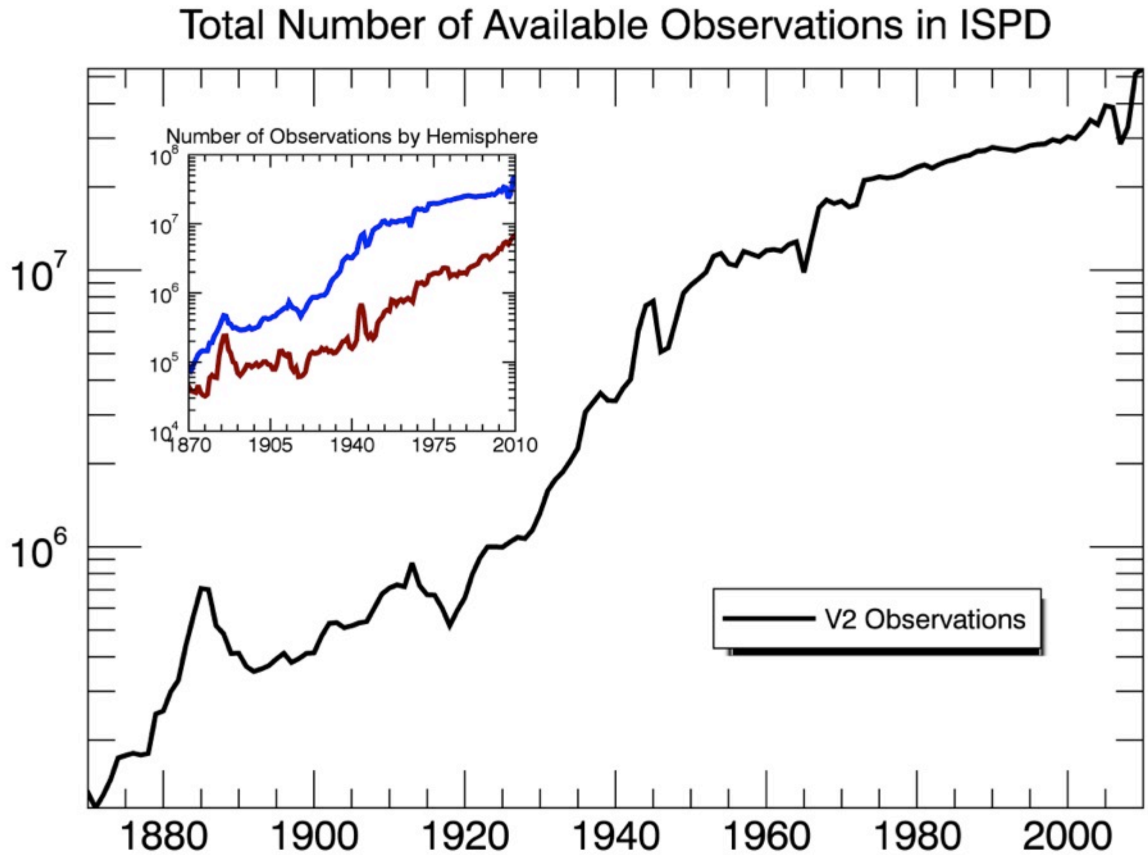


Figure 4. Time series of the number of pressure observations per year in version 2 of the International Surface Pressure Databank (ISPDv2) from 1870 to 2010. Note the logarithmic scale along the y-axis. Inset panel: Time series during the same period showing the number of observations in the Northern Hemisphere (blue curve) and Southern Hemisphere (red curve).

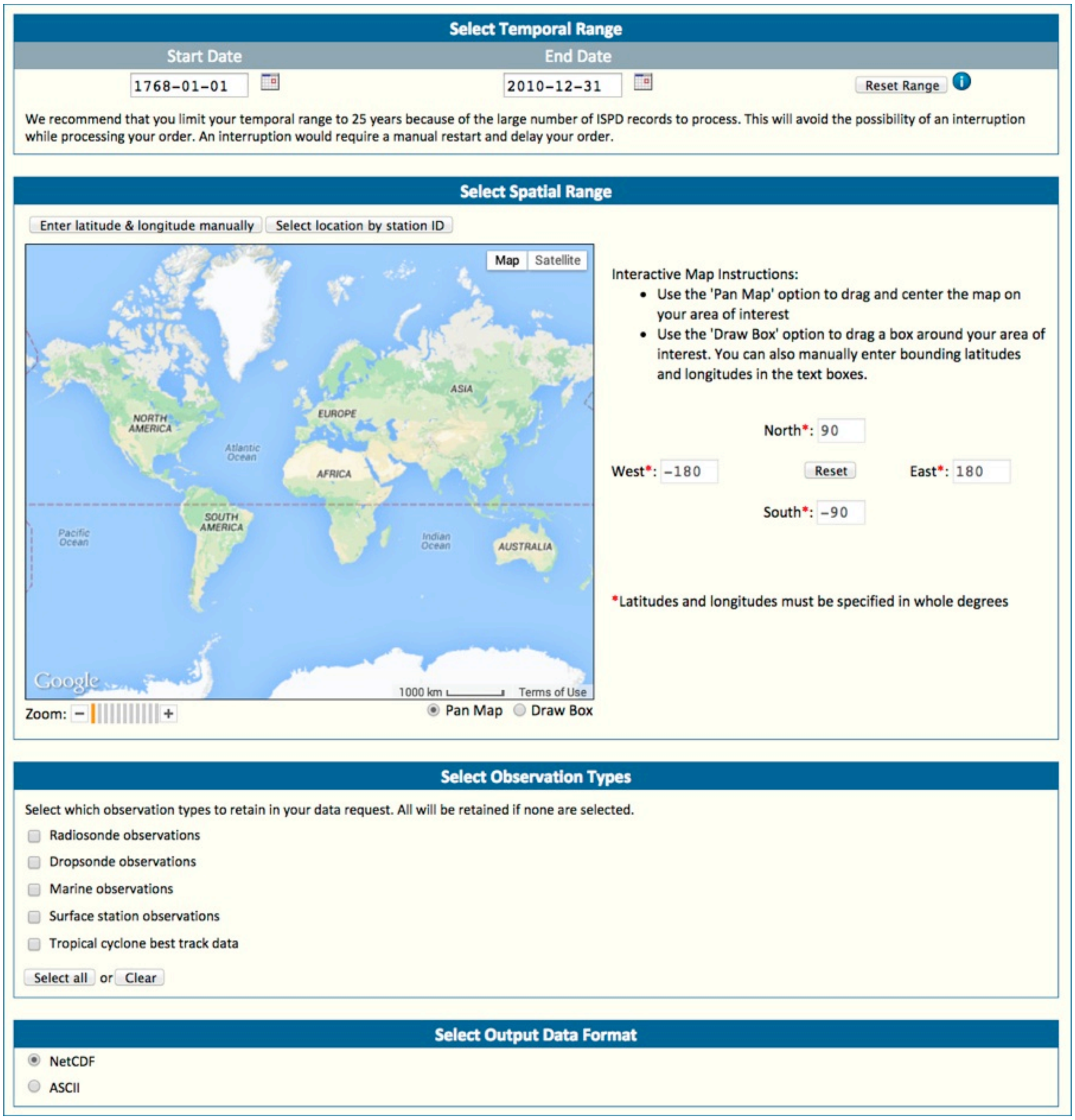


Figure 5. The data subsetting interface found on the ISPDv2 Research Data Archive webpage after user authentication. Users choose temporal range, spatial selection (choices are interactive map functions, manual latitude/longitude entry, or station identifier entry), and also can select one or many observation types, and ASCII or NetCDF output data formats.

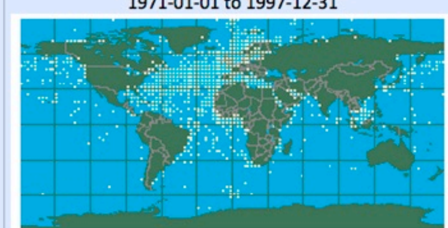
Summary for Platform Observations in HDF5 Format			
Observing Platform	**Observation Type** • **Data Types**	**Average Frequency of Data** (varies by individual platform ID and data type)	**Temporal/Geographical Coverage** (each dot represents a 3° box containing one or more observations)
CMAN Station	Surface • Assimilation feedback parameters • Observed sea level pressure (hPa)	• 1 to 6 per minute • 1 to 51 per hour • 1 to 20 per day	1983-01-01 to 2011-12-31 
Coastal Station	Surface • Assimilation feedback parameters • Observed sea level pressure (hPa)	• 1 per day • 5 per week	1986-01-01 to 1989-12-31 
Drifting Buoy	Surface • Assimilation feedback parameters • Observed sea level pressure (hPa) • Observed surface pressure (hPa)	• 1 to 10 per minute • 1 to 50 per hour • 1 to 20 per day • 1 to 6 per week • 1 to 4 per month • 1 to 10 per year	1899-01-01 to 2011-12-31 
Fixed Ocean Platform	Surface • Assimilation feedback parameters • Observed sea level pressure (hPa)	• 1 to 7 per hour • 1 to 11 per day • 3 per month	1971-01-01 to 1997-12-31 

Figure 6. Example of the content metadata interface found on the ISPDv2 Research Data Archive webpage. Here users can view and investigate tabulations of the location, observation type, platform identification, and maps of the global distribution of observations for the full dataset.

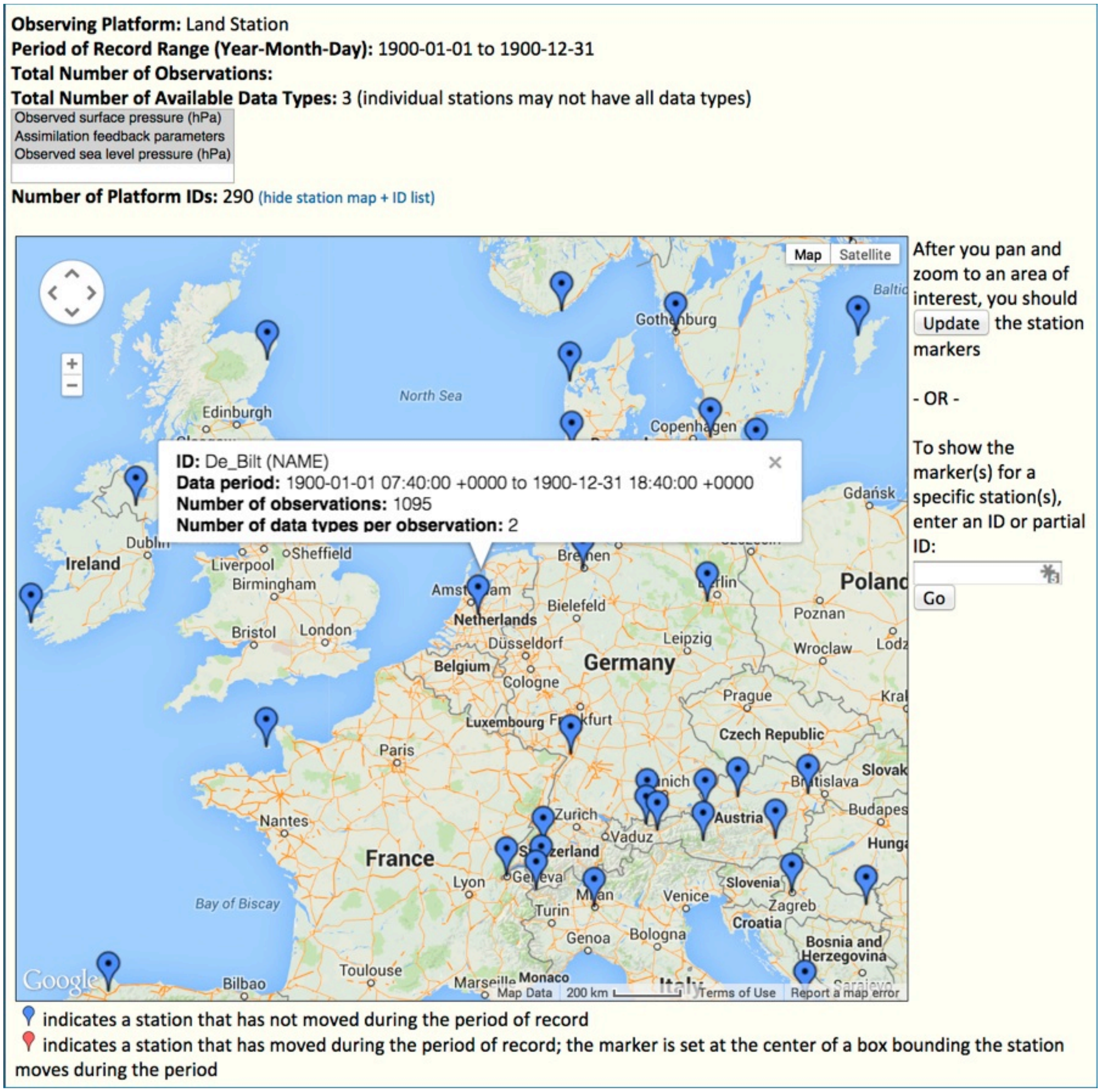


Figure 7. Example of the file content metadata interface for the yearly tar files found on the ISPDv2 Research Data Archive webpage. This service enables users to probe the ISPDv2 via an interactive map of land station locations, and more efficiently search for the observational data at any particular time and region of interest.

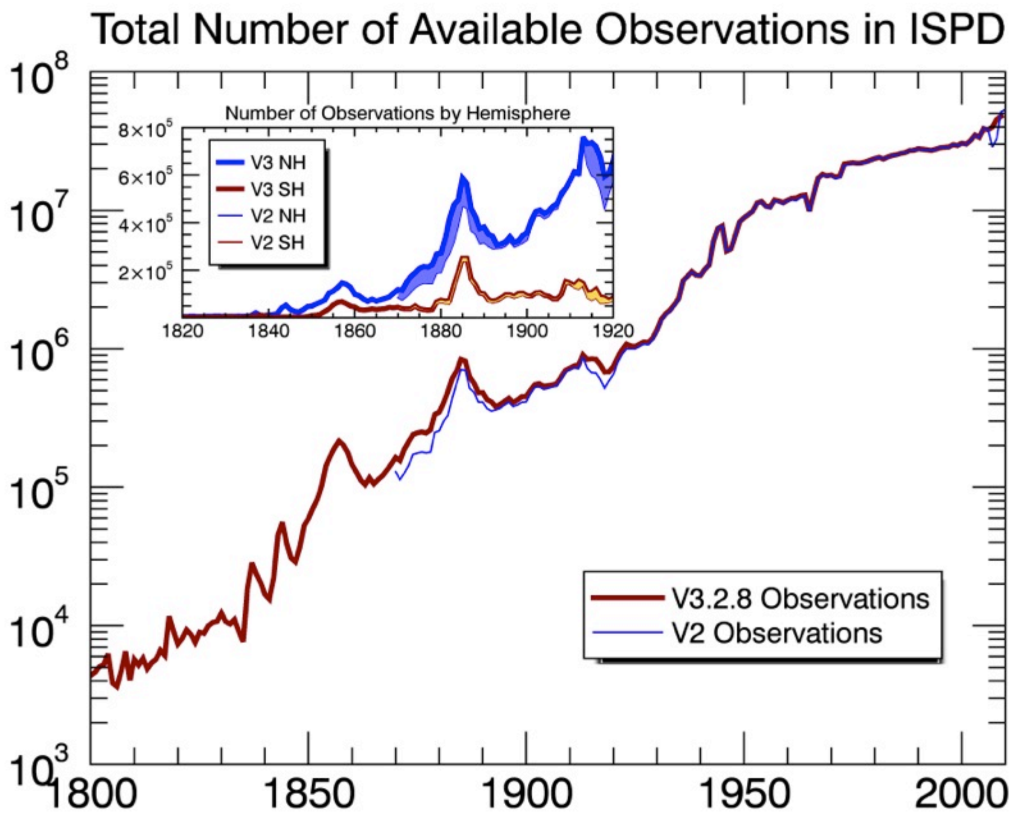


Figure 8. Time series of the number of pressure observations per year in version 2 (thin blue curve) and version 3.2.8 (red curve) of the International Surface Pressure Databank (ISPD) from 1800 to 2011. Note the logarithmic scale along the y-axis. Inset panel: Time series (shown on a linear scale) during the period 1820 to 1920 showing the number of observations in the Northern Hemisphere (blue curves) and Southern Hemisphere (red curves). The shading highlights the gain in observations between the two versions.

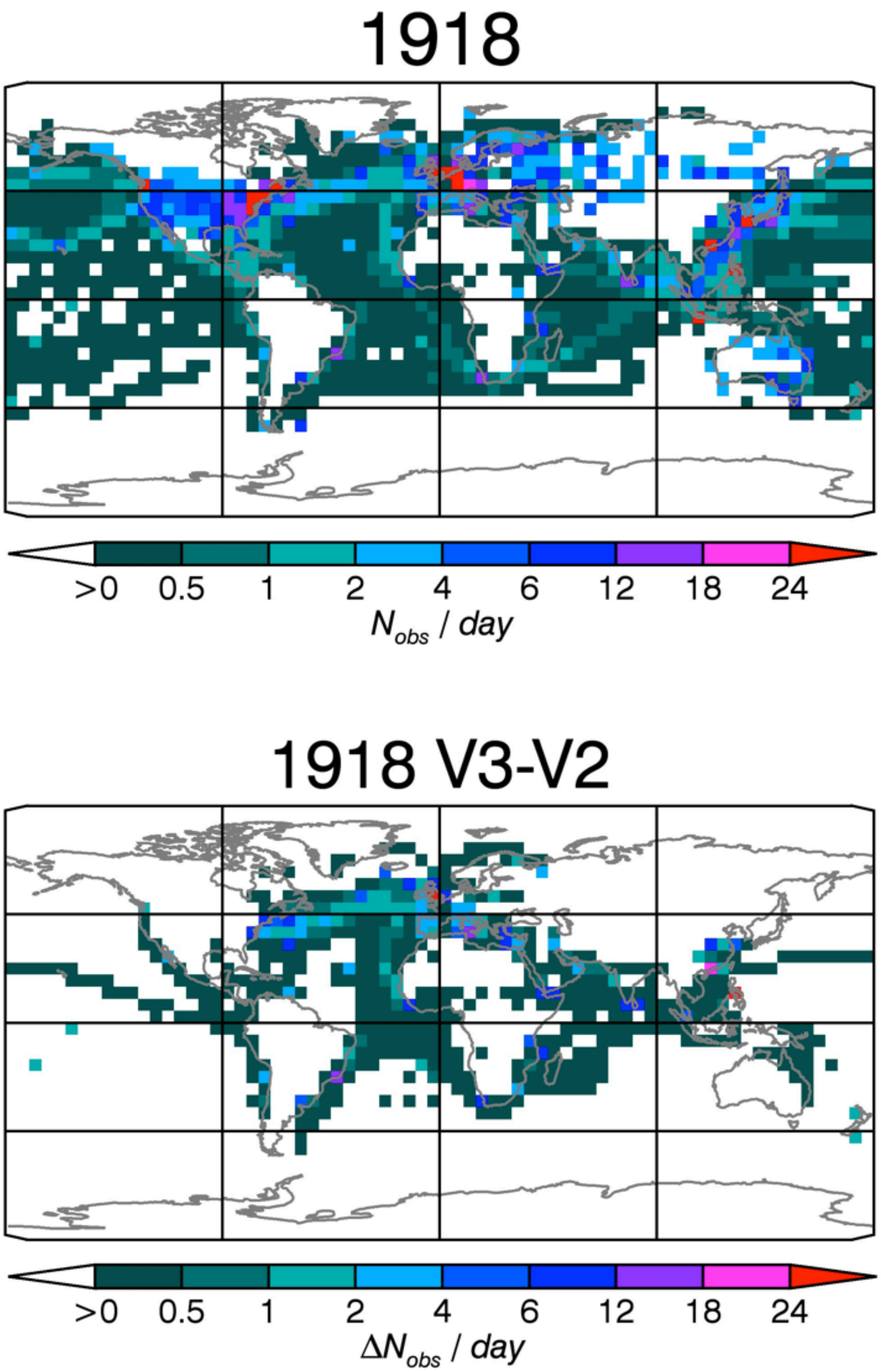


Figure 9. Upper panel: Map showing the daily average number of pressure observations in the new ISPDv3.2.8 for the year 1918. Lower panel: Difference between the daily average number of pressure observations between ISPDv3.2.8 and the ISPDv2 (cf. **Figure 3**). Counts of observations are made in five-degree grid boxes.